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Converting Existing Copper Wire Firing System to a Fiber-Optically Controlled Firing System for Electromagnetic Pulsed Power Experiments

by Robert Borys Jr and Colby Adams

NOTICES

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14. ABSTRACT

To safely conduct high-voltage pulsed-power experiments in Experimental Facility 167 (EF 167), the existing firing system needed alterations. The copper firing line of the range provided a current path from the experimental chamber to the control room, posing a risk to operators and equipment. To circumvent this hazard, the copper firing line was replaced by an optical fiber, effectively isolating the control room from electrical hazard. Implementation of the new fiber system used much of the existing resources in EF 167, making this an improvement that can be implemented in any range requiring electrical isolation with a quick turnaround and at low cost.

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1. Background and Introduction

After an extensive review from the US Army Research Laboratory (ARL) Electrical Safety Office, it was determined that the existing firing system in Experimental Facility 167 (EF 167) was not adequate to safely perform pulsed-power experiments with gunpowder- or air-driven guns. This firing line used solid copper wire, which provided a continuous electrical conduction path between the high-voltage capacitor in the test chamber and the firing/control room, where personnel are stationed when experiments are performed (Fig. 1). This poses a safety risk since high voltage can travel from the test chamber and potentially result in personnel injuries and damaged equipment.

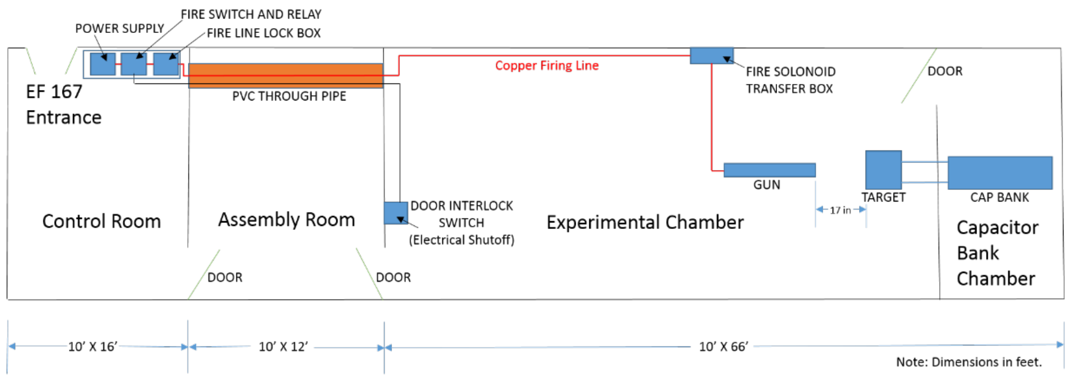

Fig. 1 Schematic of the EF 167 layout. The copper firing line delineated in red provided the offending current path in the old setup.

To mitigate this electrical risk hazard, the firing system was refurbished to operate using a fiber-optic line, which would electrically isolate the firing room from the test chamber. Several additional improvements were implemented to lower hazard risk and are described herein. Although these improvements were focused on pulsed-power operation, some should be considered for safe electrical operation for any experiments performed within ARL laboratories.

2. Objectives for Fiber-Optically Controlled Firing Unit

The primary objective of refurbishing the firing unit was to electrically isolate the firing room from the test chamber. Doing so required a cost-efficient solution to update the hardware involved in the firing process. With the updated hardware, it becomes necessary then to revisit the procedures used in setup and preparation of the gun for fire.

As a means of mitigating cost, much of the old equipment was repurposed for the safer firing module. Changes made to the housing and wiring to simplify the interface of the system are shown in Fig. 2. Since the walls between the control, assembly, and experimental chamber rooms are made of steel, electrically insulating polyvinyl chloride (PVC) through pipes as well as nonconducting cable trays to the firing solenoid were installed and used to thread the fiber-optic lines between the rooms. New equipment was also added to the system including the fiber-optic line with associated converters and an arbitrary waveform generator. Total cost to convert the experimental facility from a copper firing line was approximately $1,000.

Fig. 2 Rear-face view, old (left) and new (right) fire switch and relay box. Note the reduced wiring on the new fire switch and relay box, elimination of finger protection, and elimination of the electric bus bar.

3. Operation of the New Fiber-Optic Firing System

The new fiber-optic firing system has a similar configuration to the old copper wire system. A single switch initiates the process, which fires the gun. The firing box contains 2 relays with various inputs and outputs, as shown in Fig. 3.

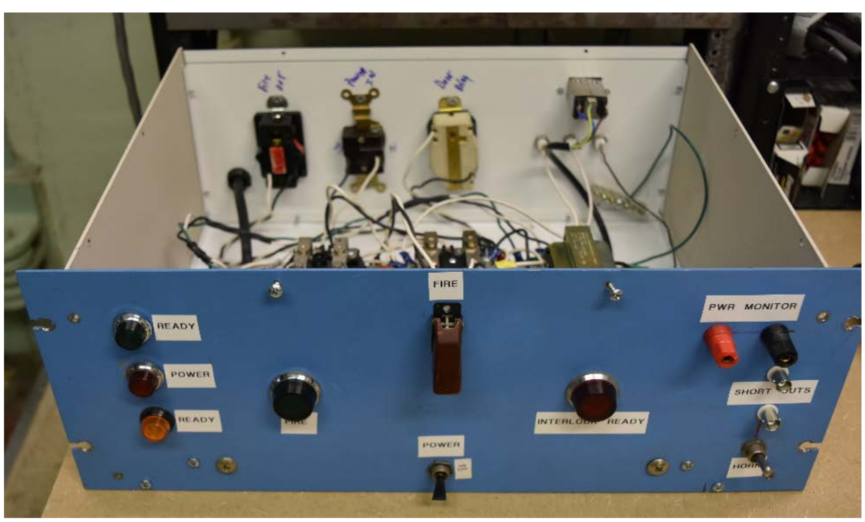

Fig. 3 Front-face view of the new fiber-optic fire switch and relay box

An interlock system ties a switch from the door between the assembly room and the experimental chamber to the first relay in the firing box. Unless the door to the experimental chamber is closed, the relay in the firing box will remain open to prevent accidental firing. If the interlock switch on the door is engaged, triggering the fire switch closes the second relay in the firing box. When this relay closes, it completes the circuit running from the firing box to the make-screen box. The make-screen box recognizes the completed circuit as a “made” connection and outputs a 5-V transistor–transistor logic (TTL) pulse to the external trigger on the arbitrary waveform generator. Receiving this pulse triggers the waveform generator to output a 5-V pulse for a duration of 1.5 s. The inclusion of the waveform generator is necessary because the output from the make-screen box is of insufficient duration to properly fire the solenoid. The pulse from the waveform generator is fed into a BNC-to-fiber converter and is transmitted via fiber to the experimental chamber room. In the experimental chamber, the fiber is connected to another converter located in a lockout box. It is very important to note that during preparation and experiment the single key to open the otherwise closed lockout box is only retained by the approved gunner.

Inside the lockout connected via the BNC-to-fiber converter is a 5–300 V control relay, shown in Fig. 4. When the 1.5-s pulse is applied to the relay, it allows 145 VDC to pass through to the firing solenoid, assuming the firing line is in the armed position. The firing line is kept locked in the box and in the “safe” position until the experimental chamber is announced to be clear of personnel by the test director, as shown in Fig. 5.

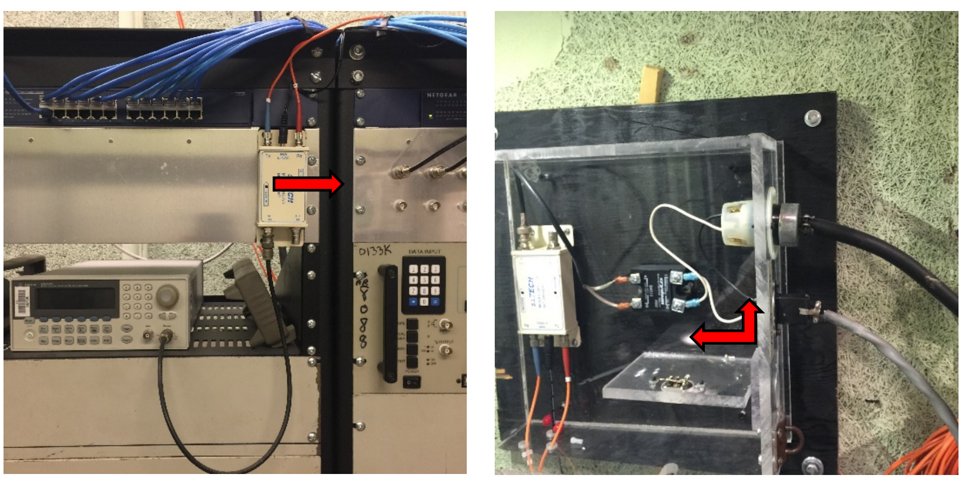

Fig. 4 (Left) Arbitrary waveform generator and red arrow showing the BNC-to-fiber converter. (Right) Firing line lock box and red arrow showing the fiber-to-TTL converter with the 300-V control relay.

Fig. 5 The firing line (gray) is shown in the safe position secured at the bottom of the lockout (red arrow). During a test, this will be moved to the firing position on the right side of the box just below the incoming line from the power supply.

The line from the relay to the solenoid is mostly protected; however, a small portion of the line is exposed to potential damage. This portion of the firing line is sacrificial and made to be easily replaced. A terminal strip mounted to the wall inside a polycarbonate casing provides a quick means to replace the expendable cable after each shot, as shown by the red arrow in Fig. 6.

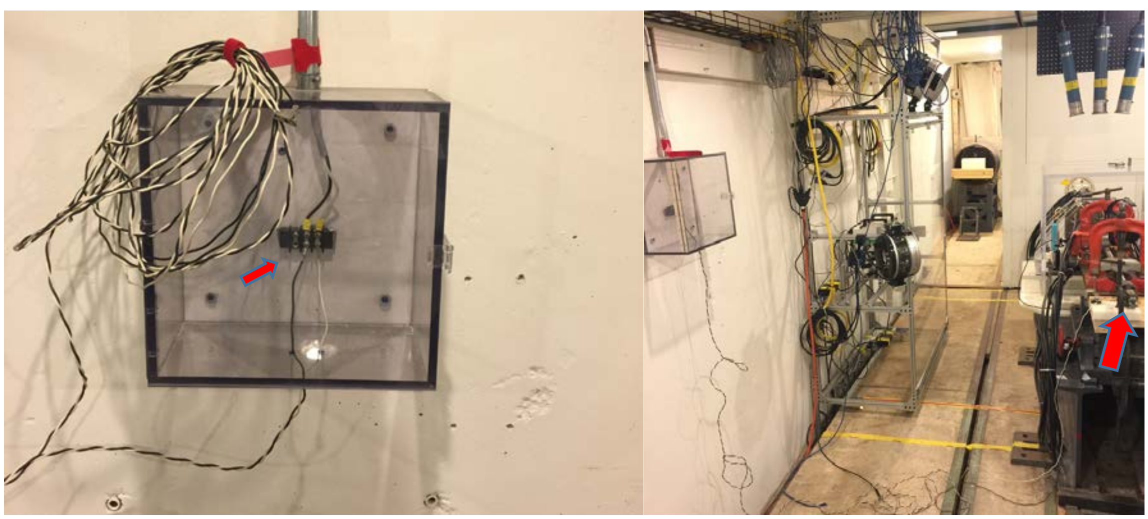

Fig. 6 (Left) Expendable cable and relay-to-gun solenoid box located in the experimental chamber room. (Right) Relay-to-gun solenoid box mounted on the concrete wall and the red arrow is pointing to the gun solenoid.

4. Conclusion

The implemented changes were an effective solution for reducing hazard risk to the challenges of using the indoor firing range for high-voltage pulsed-power experiments. The new system is just as straightforward to use as before but has the added benefit of electrical isolation for the control room and complying with Army and ARL Electrical and Explosive Safety Standards. Most hardware from the old system was reused as a means of minimizing costs but improving safety. The overall implementations were significant improvements to EF 167 capabilities and directly contributed to the approval of SOP 385-0903, *Safe Operation of High Voltage Capacitor Banks up to 280 Kilojoules at ARL Experimental Facility 167*.

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